Success with electronic eyes

– how the way in which the eye detects light can be used for industrial purposes and artificial intelligence.

An opto-based microchip implemented in standard CMOS technology has made it possible for DELTA to deliver a new type of chip which can be used within many new industrial areas that normally require a pair of eyes. Colour recognition, 3D motion sensors, luminance detection and distance measurement, to take just a few examples, can now be produced artificially for less than USD 2 per chip.

"We expect many new applications for the chip in industries such as the medical-technical, consumer and automotive sectors. We can currently demonstrate different prototype systems for optical mice, colour recognition and controlling protective welding goggles," states Gert Jørgensen, VP Sales & Marketing. "The development, which started with a couple of strategic clients in Sweden and Denmark, means that we eagerly anticipate a bright future for intelligent optical measuring systems, more popularly known as 'an artificial eye'," he continues.

A brief history

The Danish company DELTA celebrated its 70th birthday on 1 January this year and has, over the years, solved a myriad of diverse tasks. The development of microchips began over 25 years ago and more than 25 million chips now pass through DELTA each year. For 40 years, DELTA has also developed and produced advanced optical filters, either in the form of custom or standard filters. Today, DELTA supplies optical filters to clients all over the world. DELTA has drawn from these two unique, specialist areas to create a brand new product: the artificial eye.

At the same time, DELTA was part of the development within MEMS technologies (Micro-Electro-Mechanical-System), when these, during the 1990s, developed into various intelligent electromechanical sensors. With these small, robust systems you could suddenly measure parameters such as pressure, acceleration and temperature and thus use them for industrial purposes. Today, MEMS forms the basis for many control and security systems within the car industry, as well as control systems for industrial and household purposes.

At that time, you could house microchips and sensors together in order to make them more reliable and because this meant you could produce intelligent sensors. Relatively few people know that in fact the casing also fulfilled a function since the same microchips are sensitive to light. We wanted to control the amount of photonic energy which was introduced to the diodes on the electronic circuits as the electrical functionality could be changed as a result of the photons.

Today we actually use this light energy (photonic energy) at different wavelengths when we want to control and read with light. This principal is now used for image creation, when you create electronic images with modern cameras. In this instance, images are formed by controlling the wavelengths a diode is exposed to.

Our idea of optical eyes as motion sensors

Our ideas arise from the more industrial application areas where we use lasers or other light sources to generate photonic energy at a certain band and then measure the reflected photonic energy with an optical eye. This means that you measure the photonic energy at a specific transmitted wavelength, e.g. a laser beam in the 800–900 nm range and then measure the reflections of the photons. This principle can be applied to many different on-chip sensor elements.

In the figure below, we have placed a light source in the same plane as our sensors. With the aid of reflections and a lens patent issued and implemented in cooperation with Risø and the system house OPDI Technologies, it is possible to measure distance, 3D motion and positions. This is done by taking a small image section consisting of 4–9 diodes. Then the photonic energy is measured in the individual diode as a function of time. The photonic energy is converted into voltage which is then observed in the diode array. The voltage of the individual diode is then an expression of how much photonic energy there is in the reflected laser light. In the event of the surface moving, the reflected light energy will move across the individual diode which will then, in conjunction with specially developed software, calculate 3D motion. By being able to detect this 3D motion, the system can be used as a laser computer mouse or a simple trackpad system for a mobile phone. Similarly, the light system could be used to measure distance based on the same three-dimensional functionality.

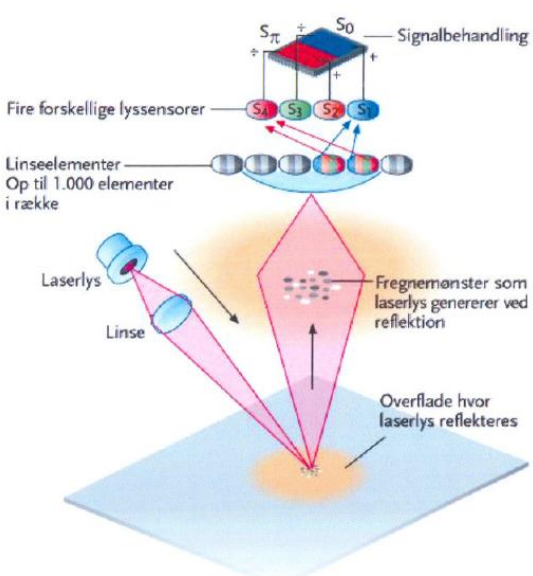

Figure 1: Schematic diagram of a laser system that can be used as a computer mouse or trackpad in mobile devices. The laser hits a surface which is then reflected irregularly and back to a patented lens system. The laser light continues onto a diode array which collects and calculates the light energy as a function of time. The motion can then be calculated. The system can be used in a long row of optical 3D motion detectors. This can replace the earlier mechanical 3D motion sensors primarily found in consumer electronics such as laser computer mice or trackpad devices in mobile phone that were, implemented according to capacitive or inductive principles.

The chip, which implements the above functionality, has already been certified and integrated in many products which will arrive on the market fairly soon. OPDI Technologies, Risø and DELTA have great expectations for a bright future within handheld electronics for this particular method of managing 3D motion detectors.

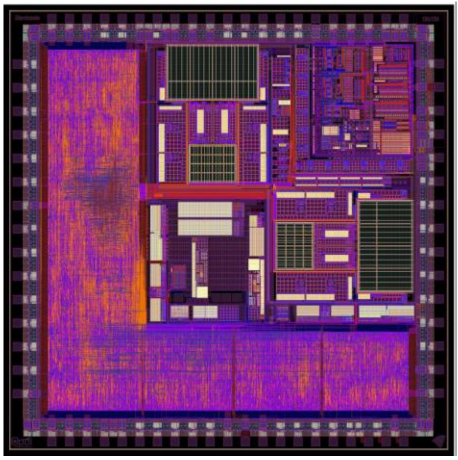

Figure 2: The first optical chip for motion detection. The chip comprises digital functions which are designed to transmit control signals to the rest of the system (mobile phone, GPS, etc). There are also analogue functions that convert light energy to voltage – these are called transimpedance amplifiers.

The chip can be used as an artificial eye to take brightness measurements

Having experienced sunny days, we know that it's great to have a pair of sunglasses. From a purely practical point of view, what actually happens when we put on a pair of sunglasses is that we turn down the energy that the eye sees. Adjusting the light content by putting on a pair of sunglasses actually means that we're turning down the luminance. In principle, what we really want to do with this chip is to determine the luminance in relation to what the eye sees and then use this detection to control windows, glasses, TV screens, GPS receivers or instrument panels in cars.

In order to decide the energy (luminance) that a human eye sees, we place different filters over the chip in the areas where the diodes are located. We have to use two filters in order to be able to determine the photonic energy in the wavelength ranges that the human eye can perceive. We can choose to place a red filter in front of a diode and measure the energy. This will measure the energy in a normal eye's field of vision but also in the infrared range. Here there is typically a lot of energy which we normally perceive as heat. Infrared rays are created by the sun and are harmful to the eye in large amounts. To get a more accurate picture of the energy content, these wavelengths need to be filtered out. This is achieved by measuring the energy content through a green filter. Photonic energy behind a green filter does not contain infrared rays and therefore you can, with great approximation, mathematically add together the energy from these two filters to get a proper idea of what type of luminance can be found in the field the two diodes can see. In other words, we have implemented a luminance sensor which measures the energy that the eye perceives. We can use this to turn the brightness level up or down on TV screens, mobile phones and many other light-sensitive applications in order to save power and batteries. At the same time, we can also create sensors that can be used to protect the eyes. We envisage sunglasses, skiing goggles, motorcycle visors, welding helmets, etc.

DELTA in cooperation with IBM Microelectronics

As if it was not enough that optical sensors are finding their way into many applications, DELTA's extensive experience of ASIC technology has meant that many of the industry challenges have already been solved. "We use standard CMOS technology for the optical chips, making our sensors much cheaper than our competitors," says Gert Jørgensen, VP Sales & Marketing. Normally chips used in photo applications are produced in silicon wafer, which is especially useful for optical purposes. DELTA's opto-chip is implemented using normal CMOS processes and this makes the price of our chips very attractive. DELTA's opto IP has so far been implemented and certified by three silicon wafer suppliers, IBM Microelectronics being the latest. "DELTA will probably have finished the IBM technology prototypes by the end of Q2 this year," says Jürgen Hilsberg of IBM Microelectronics. IBM envisages that DELTA's IP will be used for intelligent light ('Street Lightning') and other applications.

Both the optical design and the application of prototype filters will be completed by DELTA in Hørsholm. At a later date, once the chip is selling in high volumes, DELTA's business partner in China will dope the optical filters directly onto the diodes.

Right now the next step is being planned: testing. With more than 30 years' experience within the electrical testing of microelectronics, DELTA will now also work with the parameter of luminance or light sensitivity. This produces challenges, as we really want to use a parallel test in which several opto-chips are tested simultaneously. "We estimate that we should be able to test 10,000 chips an hour," says Eskild Jensen, who runs the testing department in Hørsholm. That corresponds to 3 chips a second, which is quite fast. In comparison, testing an individual chip typically takes 3–4 seconds.

IP as prototypes for clients – a new design strategy

In order to help our clients get up and running in optics, DELTA has developed various prototype ideas which our clients can use straightaway. We have prototype opto-chips consisting of diodes, filters, etc. Delivering prototypes of our sensors is a new design concept at DELTA which gives our clients the opportunity to experiment and 'play' their way to solving tasks. We will use this new concept within opto-ASIC and this can be compared with what we have previously done with the FPGA solutions within complex SOC designs. DELTA has a great deal of application knowledge within opto and ASIC areas and really wants to help clients get going while at the same time verifying 'Proof-of-Concept', before an opinion is formed about an actual development project.

We have now worked with these technologies for more than 20 years and optics/ASIC engineers have worked together on development projects for more than four years. We believe that the future lies in combining optics and ASIC technologies. A complete development project can cost up to DKK 2–3 million and this is why DELTA believes it is important that the concept can be tested before you go ahead with that sort of investment.

Our opto-chip can be supplied with or without optical filters according to the solution the individual client requests. At our laboratories in Hørsholm, we have equipment that can design and add optics directly onto the individual photo diodes. And if you would like advice and guidance, we can quickly assemble a team with knowledge of both optics and electronics. “You won’t find this combination of technology anywhere else in Scandinavia,” says Gert Jørgensen.

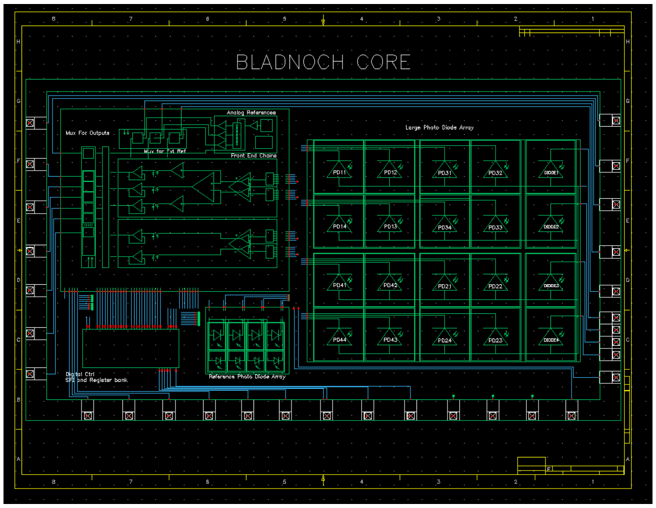

Figure 4: Our prototype, which has both large and small diodes in different locations on the chip. This means that clients can come up lots of different tests in their efforts to develop the optimal optical design.

Clients are welcome to contact us

Clients can always contact DELTA to get hold of prototypes. You have to sign an NDA and business agreement, which ensure that the recipient of the prototypes does not simply copy our ideas and know-how. During the development phase, we will of course be prepared to explain how the principles work and how the sensor is used. If there is a need for more tangible, practical knowledge, we will gladly draw up a commercial agreement.

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